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CONTENTS

ARTICLES

A Method of Replacement Analysis
J. A. Nordin 1

N.A.A. Research Report No. 35
Alan G. Bates 20

REVIEWS

Engineering Economics for Professional Engineers' Examinations. By Max Kurtz.
Anatole R. Gruehr 31

The Capital Budgeting Decision. By Harold Bierman, Jr. and Seymour Smidt.
W. B. Thulin 35

The Appraisal of Capital Expenditure. By C. D. Edge.
Arthur Lesser, Jr. 38

Railroad Equipment Financing. By Donald M. Street.
Louis Siegelman 41

NOTES 30

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A METHOD OF REPLACEMENT ANALYSIS

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I. INTRODUCTION

The replacement-analysis method presented below will be called the total-discounted-expenditure (TDE) method. It is applied only to simple conditions, but ways of dealing with complications are outlined. A significant part of the case for the method is the contention that it can deal with certain complexities better than the leading current methods can. (For convenience in exposition, discussion of these methods will be deferred until the TDE method and a numerical example have been presented.)

A preliminary statement of the problem: Given a machine installed at time 0, find the chain of replacements that will minimize the present worth of total expenditures over a selected period. (A more complete statement of the problem appears on page 6 below.)

II. ASSUMPTIONS

The assumptions used are simplifications of the industrial situation and of the decision-making process. Removing a "major" simplification might suggest a change to a method radically different from the TDE method; the TDE method can be adjusted for the removal of "minor" simplifications. Thus "major" and "minor" are defined in relation to the exposition process; a minor simplification is made only to facilitate exposition.

"Minor" does not mean "unimportant for practical work". Practical work may require removal of a minor simplification, and removing it may be easy. (The simplification that obviates taxes is an example. See page 15 below.)

A. MINOR SIMPLIFICATIONS OF THE INDUSTRIAL SITUATION

1. Nature of the Machines

The original and all the machines in the chain of replacements can be used for just one purpose; e.g., rolling cigarettes. It is expected that the design of machines is to be improved as time goes on, the improvement being shown by a reduction of operation and maintenance expenditures per unit of output.

2. Machine Separable

The machine can be treated as an individual piece of equipment, although management may intend to conduct a later analysis to decide on replacement of a complex of which the machine is a part.[1]

3. Constant First Cost

The first cost of any replacement is a constant over time.

4. No Downgrading

A machine must be used only for the purpose for which it was intended when it was installed.[2]

5. Lead Time

During the lead time for a new machine, the machine is not used at all.[3] The cost of bringing the new machine through the lead time and making it ready to produce at its maximum efficiency is included in the first cost of the machine.

6. Constant Salvage Value

Salvage is a constant number of dollars, regardless of the age of the machine at retirement, and the time when it was installed.

7. Operation and Maintenance Expenditures

At time t the rate of operation and maintenance expenditures

[1]On the machine as part of a complex, see Harold O. Davidson, "The MAPI Formula - Estimating Function or Analytic Model", the Journal of Industrial Engineering, Vol. VIII, No. 3, May-June 1957, p. 187.

[2]On downgrading, see Harold O. Davidson's review of George Terborgh's Business Investment Policy, in the Engineering Economist, Vol. 4, No. 3, Spring 1958, p. 23.

[3]See Harold O. Davidson, op. cit., p. 24.

for a machine installed at time τ is $e^{-a\tau + b(t-\tau)}$, where a and b are positive constants, and e is 2.718 ...

8. No Taxes

9. No External Capital Rationing

Having announced the interest rate at which management can borrow, the lender imposes no restriction on the amount of money to be borrowed.

10. No Inflation Expected

B. MAJOR SIMPLIFICATION OF THE DECISION-MAKING PROCESS

There is just one major simplification of the decision-making process, on the basis of the major-minor distinction mentioned above: all uncertainty can be dealt with adequately by using certainty equivalents. (Given a probability distribution for a variable y, then y^* is a "certainty equivalent" for the distribution for a given decider, if the decider, faced with the distribution, acts as he would act if faced with one value y^*, subject to no uncertainty.) All quantities used are to be thought of as certainty equivalents.

C. MINOR SIMPLIFICATIONS OF THE DECISION-MAKING PROCESS

There are six minor simplifications, the removal of each of which requires only minor adjustment of the TDE method.

1. Planning Period

A specific planning period, from time 0 (the present) to time T, is used. Management is concerned about events during the planning period, but not about events later than the end of the planning period. T can be chosen conveniently for the problem at hand; even if T is a large number, discounting will guarantee that present decisions will not be unduly influenced by estimates pertaining to events in the remote future.

2. Profit Motivation

Management wants to maximize the sum of discounted expected future profits over the planning period.

3. Discounting

Each expected future revenue or expenditure is discounted to the present at a constant discount rate r, and discounting is continuous. (The discount rate may or may not be equal to the rate

at which management can borrow money.)

4. No Internal Capital Rationing

Management's fear of uncertainty does not deter it from borrowing heavily enough to maximize the present worth of expected future profits over the planning period.

5. Constant Output Rate

(Thus we can deal with expenditure minimization rather than the more general problem of profit maximization.)

6. Adjustments at End of Planning Period

Suppose that the sensible time for the (n+1)th replacement would be τ_{n+1}, which is greater than T. The adjusted first cost of the nth replacement is chosen as

$$\frac{A(T-\tau_n)}{\tau_n-\tau_{n-1}},$$

where A is the first cost of the replacement.

III. THE MODEL AND A NUMERICAL EXAMPLE

A. ESTIMATION

Most writers on replacement agree that extensive estimates are necessary, and that the estimation process ought to be specified in detail. But there is disagreement about the kinds of estimates to be made, and the relations among the estimates.

Suppose that A depends upon B and C, that B cannot be outside the range 9 to 11, that we are highly confident that B is on the range 9.9 to 10.1, that C is known to be on the range from 10^{-20} to 10^{-50}, and that any value on this range is as likely as any other.

If A is the sum of B and C, perhaps A can be estimated usefully, even though C cannot. But if A is the product of B and C, a given percentage of error in estimating C causes the same percentage of error in estimating A.

Perhaps it is hard to decide whether the principal relations are essentially "additive" or essentially "multiplicative" in a given problem. Consider, however, the fact that Joel Dean is willing to estimate the economic life of a machine, although he is unwilling to estimate the future course of operating and maintenance

expenditures.[4] If management is unable to estimate sensibly the operation and maintenance expenditures for a machine, it is unable to estimate sensibly the economic life of the machine.

Similarly, E. L. Grant writes, in connection with a choice between a short-lived replacement and a long-lived replacement:

> "Where it is forecast that the shorter-lived asset will be replaced with an asset that will, over its life, have lower annual costs than those of the longer-lived asset, this forecast is an element in the economy study that is favorable to the selection of the shorter-lived asset. The real question for the analyst to decide is whether or not to place a definite money value on this prospect. More often than not, the uncertainties surrounding any estimates of the exact superiority of future assets to present ones are so great that it is more sensible merely to treat this prospect as one of the irreducible factors favorable to the shorter-lived asset."[5]

Grant presents no argument in favor of his conclusion that uncertainty makes it inadvisable to avoid making an estimate. In general, it pays to estimate the mean of a probability distribution, even if the dispersion associated with the distribution is known to be large.

The TDE method involves estimating every quantity that is important in predicting profits during the planning period. Some estimates are subject to considerable uncertainty; but if we did not make them, we should be acting as though uncertainty were inferior to complete ignorance.

[4] Capital Budgeting (Columbia University Press, New York, 1951), p. 98.

[5] E. L. Grant, Principles of Engineering Economy, 3rd ed. (The Ronald Press Company, New York, 1950), p. 548. The use of the phrase "irreducible factor" is mildly unfortunate. The phrase has the connotation of a mathematical term which is the product of unknown factors. Grant's usage suggests that there is some way of estimating the terms without estimating the factors whose product the term is. But, in general, this picture corresponds to nothing in business operation. A person estimating a term that he calls an irreducible factor ought to show that his estimation procedure is logically independent of the process of estimating the individual factors.

If we formulate our estimation processes carefully, we can try to improve them individually. Perhaps each estimation process can be improved by a group of experts centering its attention on that one process. By estimating the values of "irreducible factors" we conceal the limitations of our knowledge, and thereby isolate ourselves from influences that might mitigate the limitations.

B. THE MODEL

At time 0 we install a machine whose first cost is A, and whose salvage value will be Ac whenever it is retired. A and c are constants.

At time t the operation and maintenance expenditure rate for a machine installed at time τ is $e^{-a\tau+b(t-\tau)}$, where a and b are constants. The rate of improvement of machines is indicated by the factor $e^{-a\tau}$, related to obsolescence. The deterioration of a machine through the interval (τ,t) is indicated by the factor $e^{b(t-\tau)}$.

The present worth of a one-dollar expenditure rate at time t is e^{-rt}, where r is a constant discount rate.

There are no expenditures other than the first costs of machines (reduced by the salvage values of the machines they replace) and operation and maintenance expenditures.

The <u>problem</u> is this: Determine a set of numbers $\tau_1,\tau_2, \ldots \tau_n$ (τ any positive number, n any positive integer, $\tau_{i+1} > \tau_i$ for $i<n$) so that the chain of replacements at times associated with τ_i will minimize the sum of discounted expenditures over the period $(0,T)$.

Let TDE be the quantity to be minimized. Then (ignoring for the time being the adjustment to be made when τ_n is close to T)

$$(1) \qquad TDE = A(1-c)\sum_{i=1}^{n} e^{-r\tau_i} + \int_0^{\tau_1} e^{t(b-r)}dt + e^{-\tau_1(a+b)}\int_{\tau_1}^{\tau_2} e^{t(b-r)}dt$$

$$+ e^{-\tau_2(a+b)} \int_{\tau_2}^{\tau_3} e^{t(b-r)}dt + \cdots + e^{-\tau_{n-1}(a+b)} \int_{\tau_{n-1}}^{\tau_n} e^{t(b-r)}dt$$

$$+ e^{-\tau_n(a+b)} \int_{\tau_n}^{T} e^{t(b-r)}dt.$$ [6]

On our assumptions, the lives of successive replacements become progressively longer. When the rate of improvement of machines is indicated by an inverse exponential function, there is declining urgency of replacement.

However, we can get a first approximation to the optimal chain by assuming that all replacements will have a uniform life. If there are n replacements, they will be put into service at the dates $\frac{T}{n+1}$, $\frac{2T}{n+1}$, $\cdots$ $\frac{nT}{n+1}$.

In this special case,

$$(2) \qquad TDE = A(1-c)e^{\frac{-rT}{n+1}} \left[\frac{1-e^{\frac{-nrt}{n+1}}}{1-e^{\frac{-rt}{n+1}}} \right] + \left[\frac{e^{\frac{T}{n+1}(b-r)} - 1}{b-r} \right] \left[\frac{1-e^{-T(a+r)}}{1-e^{\frac{-T}{n+1}(a+r)}} \right].$$

Assume that A(1-c) is 10, T is 100, a is 0.01, b is 0.04, and r is 0.03. Table 1 shows TDE for several values of n.

Table 1 suggests that the optimal life is about 16 to 20 years. (It also suggests that within a fairly wide range the

[6] In practice the analysis may be made at the first time when management is seriously considering replacement. Then the lower limit of the first integral is τ_0, the time when the analysis is conducted, instead of 0. Somewhat less conveniently, 0 could represent the time when the analysis is conducted, rather than the time when the first machine is installed.

selection of the life of a machine in this example produces only a small variation in TDE over 100 periods.)

Table 1

n	TDE
3	$52.12
4	50.47
5	50.65
6	51.10

We can improve our approximation by dropping the uniform-life assumption. Let us return to equation (1) and observe that, for any value of n, minimizing TDE with respect to τ_i yields

$$(3) \qquad \tau_{i+1} = \tau_i + \frac{1}{b-r}\left\{\ln\left[\frac{a+r}{a+b}\right] + \ln\left[1 + \frac{b-r}{a+r}\, e^{(\tau_i-\tau_{i-1})(a+b)} - \frac{A(1-c)r(b-r)}{a+r}\, e^{a\tau_i}\right]\right\}.$$

If we select τ_1 in the range 16 to 20, we can calculate the optimal τ_2. We can proceed in this way until we have some τ lying close enough to T, though being less than T, so that one more calculation would take us to a time beyond T. Let τ_n refer to the last replacement before T is reached. Then TDE can be calculated on the assumption that the nth replacement continues in service to T.

On the other hand, this procedure saddles a chain with uneconomic expenditures in some cases, because if τ_n is close to T the replacement at time τ_n may have considerable unused service capacity left at T. To take care of this difficulty, we use the sixth minor simplification mentioned above (page 4) in connection with the decision-making process.

Thus we have the TDE for one possible value of τ_1. Repeated trials with varying values of τ_1 will give the minimal TDE to any desired degree of approximation.

If we continue to the optimal first-decimal-place value of τ_1, we have the set of replacement dates as

$$\tau_1 = 17.3$$
$$\tau_2 = 35.9$$
$$\tau_3 = 56.0$$
$$\tau_4 = 77.6$$

The TDE for this set is \$50.29. On the uniform-life assumption, TDE was \$50.47 for a uniform 20-period life, and \$50.65 for a uniform 16.7-period life. The fact that removing the inaccurate uniform-life assumption makes little difference, in the TDE, is notable.

IV. COMPARISON OF TDE METHOD WITH OTHER METHODS

A. MAPI

It will be assumed that the general nature of the MAPI system is well known; only its features relevant to the present comparison will be mentioned.[7]

Terborgh does not begin his analysis with a statement about either management objectives or the period over which the objectives are to be pursued. Without providing any argument to justify his contention, he states that the correct equipment policy is that which minimizes the time-adjusted sum or combined average of capital costs and operating inferiority.[8] "Time-adjusted

[7]The basic MAPI analysis is in George Terborgh, Dynamic Equipment Policy (McGraw-Hill Book Company, New York, 1949). Only minor adjustments are made in Terborgh's Business Investment Policy(MAPI, Washington, D. C., 1958).

[8]Dynamic Equipment Policy, p. 63.

sum" means sum of discounted values. Capital cost is cost of buying replacements.

Assume that at time τ_1 we are considering putting a challenger (the "best" replacement available at τ_1) into the place of an existing machine (the defender) that had been installed at time 0. At any time t (later than τ_1) the rate of operating inferiority of the defender is the sum of two items. The first is the excess of (a) the revenue rate at time t, on the assumption that the machine in use is the best replacement available at time t, over (b) the revenue rate at time t on the assumption that the defender is used at time t. The second is the excess of (a) the expenditure rate at time t on the assumption that the defender is used at time t, over (b) the expenditure rate at time t on the assumption that the machine in use is the best replacement available at time t. A similar calculation for any time t can be made by the challenger we are thinking of installing at time τ_1.

Thus the rate of operating inferiority includes both deterioration and obsolescence.

For every period $t-\tau_1$, the sum of discounted operating-inferiority figures equals the sum as it would be if the rate of operating inferiority at each time in the period $t-\tau_1$ were replaced by the constant K_t. The minimum K_t value, found by varying t, is the adverse minimum for the machine being considered. Thus there is an adverse minimum for the defender and an adverse minimum for the challenger. The challenger replaces the defender if and only if the challenger's adverse minimum is lower than the defender's adverse minimum.

To select an optimal policy, we must consider both management objectives and anticipated factual conditions over the whole planning period. The essential defect of the MAPI method is its failure to do so. Terborgh assumes a chain of replacements in calculating the adverse minima of challenger and defender, but his calculations do not extend far enough into the future. Suppose that, for a short time after the period giving the challenger's adverse minimum, new machines will (according to present expectations) be very expensive or very poorly made. Management ought to

arrange its affairs so that no replacement will be needed during this period. But the MAPI method will not facilitate such an arrangement.

In chapter 20 of his 3rd edition, Grant seems to accept the MAPI logic in part, though his reservations about it are significant. He provides no justification for the MAPI method, however.[9]

Grant suggests[10] five reasons why it might not be appropriate to use the MAPI method in a particular situation:

> First- "The [MAPI] gradient approach may not seem to fit the best estimates regarding the years immediately ahead. For example, it may be known that a new challenger, probably greatly superior to the present one, is in the early stages of development but will not be available for several years. In the meantime no important improvements seem to be in prospect. Under such circumstances, the most reasonable capital recovery period for the present challenger is the estimated number of years before the greatly improved new challenger will become available."

This observation is closely related to an objection above against the MAPI system, to the effect that it takes no account of expectations for times beyond the period giving the challenger's adverse minimum. However, Grant makes no suggestion about dealing with the condition he mentions.

> Second- Grant notes that no "reliable" information is at hand with which to make the relevant estimates. But the answer to this objection is the same as the answer to all claims that estimation of the future is hard: there is no escape from the necessity for making the estimates. One can either do it explicitly or do it in a more dubious way by estimating economic life, as Grant does.

[9] E. L. Grant, Principles of Engineering Economy, 3rd ed. (The Ronald Press Company, New York 1950), pp. 516 ff.

[10] Op. cit., pp. 546-47.

Third- "Often there may be question whether the need for the present service will continue indefinitely. If the hazard of discontinuance of the need for the service within the next few years is deemed sufficient, it is desirable to recognize this hazard by a shorter capital recovery period for the challenger than would otherwise be appropriate. Moreover, the [MAPI] gradient approach is not applicable unless it is assumed that the need for the particular service will continue indefinitely."

In terms of the TDE method, this amounts to choosing a small value for T.

Fourth- "When investment funds are limited they should be used for the best possible projects. This requires criteria that will result in the disapproval of projects that would be acceptable if there were no limitation of funds. One criterion that may be used for this purpose is to require a pay-off period that is shorter than the expected economic life of new assets."

The objection is valid against the MAPI system. In fact Terborgh deprecates the practice of taking a company's liquid assets into consideration in connection with replacement.[11] But Grant's suggestion that a short pay-off period be used is inappropriate. The fact that money is scarce does not mean that we should choose investments yielding quick returns. Given the scarcity of money, the best investment might still be one yielding a high return over a long period, but having almost no returns in the first few years. Grant's suggestion is related to decreasing T in the model of the present paper; but this is an adjustment called for by uncertainty, not scarcity of money.

The need for a clear statement of management objectives and a clear choice of a planning period is particularly acute in choosing among projects.

[11] Dynamic Equipment Policy (McGraw-Hill Book Company, New York, 1949), p. 299.

> There is no sensible way of choosing among projects (including replacement projects) without making a tentative plan of action for the whole planning period. The fact that a particular project refers to a relatively short period means that management must decide what it will do at the end of the short period. The planning needed cannot be replaced by any simple system of choice among rates of return.[12]

Fifth- "Particularly with long-lived assets, it may be difficult to make predictions for the full economic lives. Sometimes it may be desirable to use a study period considerably shorter than the estimated economic life, and to assume a salvage value at the end of this period equal to the estimated value of the asset to its owner at that time."

This is a specious suggestion. Grant writes of "economic lives" as though they were given. In fact they emerge from the analysis being discussed. Moreover, it is infeasible to adjust salvage value without making some assumptions about events later than the retirement date.

V. SHORT CUTS

In Section III computation was simple while the uniform-life assumption was retained. Moreover, TDE was not reduced greatly when the uniform-life assumption was removed, nor was τ_1 changed

[12] A clear statement of the need for a plan covering the entire planning period is presented in Ezra Solomon's "The Arithmetic of Capital-Budgeting Decisions", in The Management of Corporate Capital (edited by Ezra Solomon; The Free Press of Glencoe, Illinois, 1959), pp. 74 ff. Solomon's discussion does not pertain specifically to replacement decisions, but is very helpful in connection with a broad range of capital-budgeting problems.

For further discussion of the difficulties involved in choosing among rates of return, see Myles M. Dryden, "The MAPI Urgency Rating", the Engineering Economist, Vol. 5, No. 1, Summer 1959, pp. 13 ff.

much by removing the assumption. (τ_1 is the only replacement date immediately important, since the analysis will undoubtedly be rerun before the second replacement is made.)

The uniform-life assumption is not seriously misleading as long as obsolescence is slight. In the present model, it would cause no difficulty if a were equal to zero. In a particular type of application, it would be helpful to experiment to see whether obsolescence is likely to be serious enough to rule out the uniform-life simplification.

VI. COMPLICATIONS

This section deals with the consequences of removing some of the simplifying assumptions made in Section II. For convenience, "complication" will be used interchangeably with "removal of simplifying assumption". Accordingly, a major complication is one that may make it desirable to change the TDE method radically; a minor complication is one that can be handled by a relatively minor adjustment of the TDE method.

A. MINOR COMPLICATIONS IN THE INDUSTRIAL SITUATION

1. Obsolescence and Operating and Maintenance Expenditures

Some form other than geometric progression may be needed in representing the time changes in obsolescence and operation and maintenance expenditures. It may also be necessary to use functions of time in place of some of the constants used above.

Changing to arithmetic in place of geometric progression would make the operation and maintenance expenditure rate at time t $\alpha+\beta\tau+\gamma(t-\tau)$, for a machine installed at time τ. (α, β, and γ are constants.) Equation (1) would be replaced by

$$(4) \qquad TDE = A(1-c)\sum_{i=1}^{n} e^{-r\tau_i} + \frac{\alpha}{r}(1-e^{-r\tau_1}) + \frac{\gamma}{r^2}\left[1-e^{-r\tau_1}(r\tau_1+1)\right]$$

$$+\cdots+\frac{\alpha+(\beta-\gamma)\tau_n}{r}\left[e^{-r\tau_n}-e^{-rT}\right] + \frac{\gamma}{r^2}\left[e^{-r\tau_n}(r\tau_n+1)-e^{-rT}(rT+1)\right]$$

Equation (4) can be approximated about as easily as (1); approximation is not difficult in either case.

Note that going from geometric progressions (in connection with obsolescence and operation and maintenance) to arithmetic progressions need not decelerate replacement. The comparison between the two cases depends on the values of the constants, as well as the forms of the equations.

If quantities varying over time are used in place of the constants A and c and the constants a and b (or the constants α, β, and γ), the partial derivative of TDE with respect to each τ_i becomes more complicated than equation (3) above. It may also be necessary to sum over several parts of the planning period.

2. Lead Time

It is assumed above that lead time can be taken care of adequately by including its cost in the first cost of a machine. But if this procedure is too simple to be useful, $e^{-a\tau}$ can be replaced with $e^{-a\tau}+Ve^{-g\tau}$, where g and V are constants, g being moderately large in comparison with a. (In this case the first cost of a machine will not be thought of as including the cost of lead time.)

3. Complexes

The machine we are thinking of replacing may be part of a complex or complexes. It may be possible to replace a complex consisting of this machine and any of several others, or of this machine and any of several pairs of other machines, etc. Conceptually no difficulty is introduced; the approximation process must be conducted once for every complex of which the given machine is a part. Given the optimal replacement sequence for each complex, choice among complexes to be replaced can be made on the basis of degree of attainment of management objectives over the planning periods.

4. Downgrading

Instead of being sold, a replaced machine may be downgraded. This situation can be treated as a special case of the phenomenon just mentioned; the stages affected by downgrading can be treated as a complex.

5. Taxes

All financial entries used could be adjusted for tax liabilities. Since some of the taxes would be taxes on revenue or profits, the revenue function would have to be introduced. Imputed costs such as depreciation charges would have to be introduced to allow for taxation on the basis of profits. In principle, the only difficulties introduced would be those connected with depreciation charges. (These difficulties would exist whatever replacement method might be used.)

6. External Capital Rationing

In this case the lender sets the interest rate at which

management can borrow, but limits the amount it can borrow. The cost-minimization process can be subject to one side condition for every time at which there is a restriction on the firm's indebtedness.

7. Inflation

It would probably be best to assume the percentage of increase in price uniform for all kinds of revenues and expenditures, unless there were a clear reason for doing otherwise. On the basis of the uniformity assumption, it would be desirable to convert all financial quantities to real terms by deflating by the price-index values expected for the future.

B. MAJOR COMPLICATION IN THE DECISION PROCESS

The only major complication to be mentioned is a possible attempt to incorporate probability considerations into the model.

The complication is major because we do not know much about the way in which people react to uncertainty. Some theorists think that businessmen react to uncertainty in terms of whole probability distributions, others that they react in terms of mathematical expectations of variables subject to probability distributions, and still others that they react in terms of "surprise functions". There has been no discernible recent progress toward agreement.

It appears that thinking of the quantities in our model as certainty equivalents of variables subject to uncertainty is about as reasonable as any other procedure that has been suggested, and simpler than most of them.

Instead of using the constants a and b in dealing with obsolescence and deterioration, we can use time functions v(t) and w(t), associated with probability functions p[v(t)] and p[w(t)], respectively. The anticipated first costs of machines and the anticipated salvage can also be considered time functions. The quantity to be minimized can be a mathematical expectation of total discounted expenditure over the period (0,T). Thus equation (1) becomes

$$(5)\quad TDE' = \sum_{i=1}^{n} e^{-r\tau_i}\left[\int_A A(\tau_i)p[A(\tau_i)]dA - \int_S S(\tau_i,\tau_{i-1})p[S(\tau_i,\tau_{i-1})]ds\right]$$

$$+ \int_{o}^{\tau_i} \int_{w(t)} e^{t[w(t)-r]}\, p[w(t)]\,dw(t)\,dt$$

$$+ \int_{\tau_1}^{\tau_2} \int_{v(t)} \int_{w(t)} e^{-\tau_1[v(t)+w(t)]+t[w(t)-r]}\, p[v(t)]\,p[w(t)]\,dw(t)\,dv(t)\,dt$$

$$+ \cdots + \int_{\tau_n}^{T} \int_{v(t)} \int_{w(t)} e^{-\tau_n[v(t)+w(t)]+t[w(t)-r]}\, p[v(t)]\,p[w(t)]\,dw(t)\,dv(t)\,dt,$$

where $s(\tau_i, \tau_{i-1})$ is the salvage value at time τ_i for a machine put into service at time τ_{i-1}. Presumably the dispersion of each of the probability distributions would increase with t.

If the model were amended as suggested, the process of minimizing the mathematical expectation of expenditure would be essentially similar to the one used above, in that TDE' would be minimized with respect to each of the τ values. The numerical approximation would take more time.

It should be noted that the probability adjustment referred to here is more difficult to make than the adjustments referred to by Elmaghraby and Orensteen -- adjustments for uncertainty where only failure and non-failure are involved.[13]

C. MINOR COMPLICATIONS IN THE DECISION PROCESS

1. Internal Capital Rationing

Assume that management has in mind some dividend pattern that it wants to maintain; this seems to be a realistic assumption. There is resistance to lowering a dividend rate, perhaps partly because doing so will depress the price of a firm's stock. Also, it

[13] S. A. Elmaghraby, "Probabilistic Considerations in Equipment Replacement Studies", the Engineering Economist, Vol. 4, No. 1, Summer 1958, pp. 1 ff.; R. B. Orensteen, "Topics on the MAPI Formula", Journal of Industrial Engineering, Vol. VII, No. 6, November-December 1956, pp. 283 ff.

appears to be usual to defer raising a dividend rate until management is convinced that the higher rate can be maintained.[14]

Assume that there is some expected pattern of revenues and expenditures for the whole of the enterprise other than the given machine; thus there is a fluctuating level of liquid assets that can be used for replacement of the given machine. At some times the level of liquid assets owned may be negative, so that management must borrow money if the given machine is to be replaced.

On the basis of the fluctuating level of liquid assets, we can construct a function r(t), a discount function which will have low values at times for which low levels of liquid assets are expected.

This adjustment would not be so far-reaching as the adjustment mentioned above in connection with probability. However, the r(t) function might be discontinuous, so that the sum to be minimized in minimizing total discounted expenditures would have to be broken into several parts.

2. Output Variation

If output is to vary, it will be necessary to include in our model the information we need in order to maximize profit. We may wish to show a demand function, in which revenue net of all expenditures (other than those connected with the given machine) is shown as a function of the output of the machine. For instance, even if a constant price of the product is assumed, we may want to adjust revenue on the basis of the extra selling expenditure needed to sell extra units of product.

In this case we need the machine's total expenditures per unit of output, rather than per unit of time. With reference to the symbols used in equation (5) we can show v and w as functions of time and either current output or cumulative output or both.

3. Choice Among Maximands

We have assumed that management wants to maximize the present worth of future profits. But another possible objective has been mentioned in connection with internal capital rationing. The model can be adapted to any of several reasonable objectives. For instance, management may want to maximize revenue, in each time period, subject to the condition that the rate of return on investment must not fall below a stated minimum.[15] With suitable adjustment for demand conditions and selling expenditures, the

[14] A good discussion of management objectives and an interesting system of evaluating management performance are provided in Forbes Magazine's "Eleventh Annual Survey of American Industry", January 1, 1959, pp. 23 ff.

[15] See W. J. Baumol, Business Behavior, Value and Growth (The Macmillan Company, New York, 1959), pp. 47 ff.

model can be conveniently adapted to this objective.

VII. SUGGESTIONS FOR FURTHER STUDY

A general method should contain elements common to the optimal specific methods to be developed for specific problems. The parts of the TDE method that may deserve to be considered, when specific methods are developed, are:

A. Selection of a planning period.
B. Specific formulation of the quantity to be maximized and the side conditions to be met.
C. Specific formulation of all assumptions.

Probably few industrial situations would force an analyst to deal with all of the complications mentioned in Section VI. In a particular case, two or three of them may be important, however.

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N.A.A. RESEARCH REPORT NO. 35*

By

Alan G. Bates
Manager, Economic Evaluation Section
Atlas Powder Company

Anyone looking for a concise description of the "return on capital" concept and its uses would do well to obtain a copy of this N.A.A. report. However, those who need guidance in the real value of return on capital in its two main uses, and a critical appraisal of the several means by which it is calculated, must search elsewhere.

Two major applications for return on capital described in this report are:

(1) Measuring periodic profit performance;
(2) evaluating capital projects.

The chapters covering these uses are based upon interviews at 44 companies, information from other companies, and published material.

The report presents a reasonably objective review of the methods for determining and applying return on capital. However, no conclusions are reached concerning the value of the applications, or the various calculation methods. On some pages a preference is implied for one approach vs. another, but no stand has been taken.

This is not intended as a basic criticism of the report, because its purpose, of describing the use of return on capital by industry, was accomplished well. However, the report unintentionally points out certain inconsistencies which cast doubt on the validity of the use of return on capital in one of its two main applications.

*Return on Capital as a Guide to Managerial Decisions (National Association of Accountants, 505 Park Avenue, New York 22, N. Y.; December 1959; 107 pp.; $2.50)

The following pages have two objectives. First, a review and commentary is given of the N.A.A. report itself. Then a critical analysis is presented on the use of return on capital in performance measurement, with the intent of focusing attention on what appear to be serious inadequacies in this use.

REVIEW OF REPORT

Space in the report is nearly equally divided between the two uses of return on capital; measuring performance (after making the capital decision) and evaluating projects (before the decision). In both of the two main parts, the report is logically organized, and reads easily. Every important aspect of the two applications is mentioned, although very briefly on some key points. As already mentioned, the reader is left to draw his own conclusions as to whether return on capital is valid for these uses, and which of several alternate methods of calculation is superior.

PART I - MEASURING PROFIT PERFORMANCE

This part begins with a chapter describing the denominator of the basic equation:

$$\text{Return on Capital} = \frac{\text{Income}}{\text{Capital}}$$

In these pages we learn that there are four different bases for valuing capital: total assets, total assets less idle assets, assets equal to long-term sources of funds, and stockholders' equity. All bases are in use, with the majority of companies choosing total assets. Some use gross assets, others deduct depreciation; the pros and cons of this question are discussed. Most companies are concerned about the effects of inflation on the value of the denominator, but few do anything about it. Practice differs on treatment of leased assets, but they are usually excluded. This chapter can come as a rude awakening to an uninformed reader, when he realizes that the possible denominators can vary over a wide range, with no convincing arguments for using one base vs. another.

The next chapter on determining income covers mainly interest expense and taxes. There is less for someone new to this subject to wonder about, but again certain inconsistencies appear. We find that companies determine returns either before or after taxes, some showing results both ways. Interest may or may not be included, since some consider it as part of the cost of capital and not a true business expense.

Then follow two chapters on analyzing profit by company segments (divisions, product lines, etc.), and on analyzing changes in return on capital. The first emphasizes the problems involved in allocating investment and income among segments, but offers no solution. The second gives some well-constructed examples to illustrate the analysis of return-on-capital results by the use of the return-on-sales ratio and the turnover ratio (sales ÷ capital).

A final chapter in this section covers the use of return on capital as a guide in pricing decisions. Since the only use discussed up to this point is for appraising past performance, this chapter seems misplaced. Pricing involves decisions for the future, and return on existing (sunk) capital should only be of significance in price setting as an estimate of future capital needs. Therefore, this chapter could well follow the discussion of return on capital for project evaluation. Pricing calculations can be based on either of the two basic types of return on investment, not just the average-ratio method described.

PART II - EVALUATING FUTURE PROJECTS

The first two chapters in this section describe the two basic return yardsticks called the "financial statement" method and the "discounted cash flow" (DCF) method. These will be familiar to most readers of the Engineering Economist, although possibly by different names.

The chapter describing the "financial statement" method (ratio of profit to investment) reveals some interesting differences in practice, again regarding what is included in the profit and investment figures. Profit may be an average for the entire project or may be estimated for one or more subsequent years. It is sometimes before taxes and sometimes after. Costs may or may

not include allocations of indirect expenses. Investment may include only fixed capital, or may also include working capital and/or initial expenses. Some companies include future capital outlays as well. Practice varies on whether to include existing assets in the investment base. As in the first part, these wide differences in approach are described, with no attempt to defend one method vs. another.

Next, the DCF method (internal rate of return, interest rate of return, profitability index, etc.) is well defined, both by description and examples. A brief section on estimating cash flows contains some good pointers such as "where equipment and facilities already owned will be utilized by a project, these items should be charged to project cost at their cash value in the best alternative use." A paragraph on risk contributes nothing of value to anyone seriously interested in this basic feature. The last part of this chapter contains a comparison which appears to stress the advantages of the DCF method and the disadvantages of the financial-statement method. Five separate points are covered, and although DCF return seems to have the upper hand by each one, no recommendation is made as to which method is preferable.

"Relationships Between Payback Period and Rate of Return" is the title of the next chapter. This contains some interesting co-relations between the payback period and DCF return for different economic project lives. One can readily see from this the limited area of usefulness of payback period, and will recognize the danger of setting an inflexible number of years as the payback criterion for all projects.

The next chapter covers, in quick succession, capital budgeting, minimum rate of return, cost of capital, present value, and lease-vs.-buy and make-vs.-buy decisions. As might be expected, the treatment is too brief to do more than whet the interest of someone new to the field. The many features of the present-value concept, and its ability to solve problems which the DCF return cannot touch, have been bypassed.

A final chapter gives some shortcut approaches to calculating the DCF return, employing excerpts from Gregory's Continuous

Interest Tables.

RETURN ON CAPITAL AS A MEASURE OF PROFIT PERFORMANCE

Many articles and chapters of books have been written praising the virtues of measuring performance by the use of this simple ratio based on balance-sheet information. To judge from various surveys, such as the one reported here by the N.A.A., much time is spent by many companies in periodically preparing comprehensive studies of the return on capital for the entire firm, divisions, products, etc. Much additional time must be required on the part of management to examine the results and draw conclusions leading to decisions and action.

Very little has been written, however, concerning the several very questionable aspects of this approach, which, in this reviewer's opinion, make return on capital an inadequate criterion for appraising profit performance. At best, it appears to be a weak tool, useful only as a gross guide to indicate trouble spots. At worst, it can be a completely misleading yardstick which does not serve the purpose for which it is intended.

The section of the N.A.A. bulletin dealing with this use of return on capital serves (although unintentionally) to highlight several of its weaknesses, without emphasizing them as real deficiencies. Other articles give these drawbacks passing recognition, but usually conclude with the generalization that a consistent approach within a company conquers all.

We will review briefly here what seem to be the primary weaknesses of return on capital for appraising profit performance.

WHAT CAPITAL BASE?

Chapter 2 of the N.A.A. Research Report itemizes the several bases used for the denominator of the return-on-capital ratio. Five or six different capital bases are used by the companies in the survey for analyzing total company performance. Some use only one base, some use more than one, depending on the intended purpose. Differences in practice range from the use of gross assets

to depreciated assets to common-stock equity. Can ratios based on all these denominators be meaningful, depending on the purpose? Is the only matter of importance to be consistent in the use of a base?

First, it can be shown (though not here) that the results obtained by the use of gross assets,as compared to depreciated assets, will often yield different relative changes between profit periods, possibly leading to different conclusions. Yet both approaches have their staunch proponents. There is also the much-debated question of whether depreciated values should reflect accelerated or straight-line depreciation. With a consistent approach, results may be comparable from one period to the next, but company practices differ so greatly that comparisons with competitors are very difficult. Similar difficulties arise with the other bases in common use, such as stockholder equity and various adjusted asset values.

An even more troublesome problem, however, is inflation. The physical assets of any long-established company were bought at various times in its history with dollars having different levels of purchasing power. Yet the reported data on gross or depreciated assets recognize all dollars as having the same value (with the exception of a few companies who adjust for inflation). It would not be unusual for the gross value of plant and equipment to be greater by a factor of two if expressed in current dollars. This may not be a serious problem when making periodic reviews of performance for a given company or segment. But it is of substantial importance when making comparisons with other companies, or other segments within the same company. One company (or division) could have been in existence for a long period, with a large proportion of its plant and equipment purchased with higher-valued dollars. A competitor could have recently installed most of his facilities with dollars of lower purchasing power. True, the more recent facilities should be more efficient and cost less to operate. But that is a separate point from the problem of inflation and would be reflected in the income part of the equation.

What value then should be used? If a company feels that

having a return-on-capital yardstick is really worth the effort, this reviewer feels that the denominator should be the best estimate of a "true" or "fair" market value for the assets. If a general manager is given full responsibility for the profit yield of a certain group of assets, he should be charged with the most realistic estimate of their value possible. It would only be coincidental if the book figure, on whatever basis, were very close to a market value. Such values may be estimated by calculating the present value of cash flows forecast to be obtained from the assets over a long period. Other methods are, of course, available for this purpose. However, as may be seen below, there is serious reason to doubt whether any such "fair" valuation is worth the effort for this purpose.

WHAT INCOME?

Cash income is easy to determine in any accounting period and (if the period is a year or less) inflation has little significance. The big problem in determining income is what value, if any, to use for the "non-cash" expenses, mainly depreciation. If the investment base represents a mixture of dollars of varying purchasing power, so does the annual depreciation deduction which is merely an allocation over time of dollars already spent.

In any year, the gross or net income tends to be somewhat of a fiction, because of the rather arbitrary nature of this time allocation of the cost of depreciable assets. Over the long run, of course (neglecting inflation), reported net income will reflect true profit.

To this reviewer, the depreciation deduction allowed for tax purposes is the most reasonable value to use in determining a net income for the numerator. This may not be a good measure of the annual reduction in value of fixed assets. However, the main benefit to the company, of depreciation, is to reduce taxes once the investment is sunk.

If one is strictly concerned with the short-term profit performance of a division, it would seem that cash income before depreciation or taxes would be the most representative figure to

use in the numerator. Since a division manager is not responsible for depreciation policy, it would seem that he should not be judged using a yardstick which reflects depreciation as a cost.

IS THE INVESTMENT BASE SUFFICIENT?

The assets which are entrusted to any management are usually thought of only in terms of the physical plants, inventories and other easily measured assets. However, the assets of a firm go far beyond such tangible factors. Probably the most valuable resources are the employees themselves. People represent a very real asset and require substantial investment before they contribute value in excess of their pay. This is the one resource which continues (in the main) to grow in value with the passing of time.

Another asset which has real, if not measurable, value is the company name and reputation, i.e., goodwill. Very few companies show anything for goodwill on their balance sheet, because there is no known way to estimate it. In real value, however, it could overshadow the assets which do show on the balance sheet. Other assets of an intangible nature include patents and technical knowledge developed from investment in research.

A return-on-capital yardstick, by definition, measures a ratio of money earned to money (or capital value) employed. This in turn is used to judge the profit performance of top or second-line management. But management is expected to get maximum utilization and efficiency from all resources under its control, and should be judged accordingly. Therefore, a quantitative yardstick which includes only capital assets is an incomplete index of management effectiveness.

It seems to this reviewer that no ratio yet proposed can be used to gauge the effectiveness of making profits in a manufacturing concern,because much more than capital resources contribute to the conduct of the business. The limit of use for a return-on-capital ratio would seem to be for analyzing investment trusts or funds where essentially all assets have a readily measured dollar value.

DO PERIODIC CHANGES REFLECT PERFORMANCE?

Short-term profits are determined by two major influences: general business conditions and the competence of management in the face of these conditions. If a good business year follows a poor one, does an increased return on capital indicate good management performance? Or were profits up in spite of inadequate management, simply because of the force of the business tide? In a recession year, did a highly competent management prevent profits from dropping as far as they might have if performance had been just average?

Companies who use return on capital for measuring periodic profit performance must recognize the influence of external factors. How, then, do they allow for them in deciding the quality of management, in order to make the decisions which must result from such a control device? Literature which promotes return on capital for performance analysis fails to come to grips with this basic problem.

TOWARD SOUND PERFORMANCE MEASUREMENT AND CONTROL

The inadequacies of this use of return on capital, discussed above, seem almost overwhelming. Most approaches used for estimating both the numerator and denominator have basic weaknesses. Even if a sound capital base can be arrived at, many important resources which represent real assets are necessarily omitted. Finally, periodic changes result from uncontrollable as well as controllable factors; the two are difficult to isolate.

A single yardstick seems impossible. How, then, can over-all management performance be measured? One approach toward which a number of companies seem to be moving is a system of budgets and standards. The main factors which are reviewed periodically are sales and costs. Actual sales are compared with budget, actual costs are compared with standard. Any degree of detail may be examined. By isolating the financial elements in this way, it is much easier to examine periodic changes and to find the reasons for them. In particular, it is reasonably easy to estimate the effect of external conditions on the various factors, compared to studying

the effect on a ratio which combines many factors.

In this system, the investment base is not included as part of the measurement. Capital assets are considered simply as part of the total "package" of resources along with people, goodwill, etc., which are drawn upon in the conduct of the business. Individual investments are analyzed by a post-audit procedure in much the same way, to determine whether the original estimates used to justify investment decision are being achieved.

CONCLUSION

The N.A.A. Research Report No. 35 is a concise, reasonably objective, presentation of the two main uses for return on capital as practiced by industry. It is useful as a reference, even though it does not pretend to do more than give broad-brush coverage. The many variations in approach to measuring profit performance are revealed, but no stand is taken on which is preferred.

In this reviewer's opinion there are several basic deficiencies inherent in the use of return on capital for performance appraisal. A suggested substitute approach, used by a number of companies, involves a system of periodic comparisons of sales and costs with budget estimates.

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NOTES

THE SOCIETY FOR THE HISTORY OF TECHNOLOGY

Founded at the beginning of 1958, the Society for the History of Technology represents the first systematic attempt to encourage the study of the development of technology and its relations to society and culture. The Society is concerned not only with the history of technological devices and processes, but also with the relations of technology to science, politics, social change, the arts and humanities and economics. For the first time an effort is being made to bring together the engineer, the scientist, the industrialist, the social scientist, and the "humanist", to promote the study of developments of mutual interest and concern.

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Further information regarding the Society may be secured from the Secretary, Melvin Kranzberg, Room 311, Main Building, Case Institute of Technology, Cleveland 6, Ohio. Requests for subscriptions should be sent to the same place.

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BACK ISSUES

Back issues still available are Vol. 3, No. 4, Vol. 4, Nos. 3 & 4, and all issues of Volume 5. For 5-year cumulative index, see Vol. 5, No. 4. Complete edition available on microfilm.

BOOK REVIEW

Review of: ENGINEERING ECONOMICS FOR PROFESSIONAL ENGINEERS' EXAMINATIONS
By Max Kurtz
The McGraw-Hill Book Co., Inc., 1959
5" x 8" - 234 pp., plus tables. $6.50

By: Anatole R. Gruehr, Head
Department of Economics
Polytechnic Institute of Brooklyn

This text is a brief and very elementary review of time-value relationships in the selection of investment alternatives. It describes methods of handling investment problems involving simple and compound interest, sinking funds and annuities, valuation of bonds, and collateral issues, all of which have come to be known under the term "financial arithmetic". It also includes one chapter on principles of cost analysis, one on continuous compounding of interest, and one on legal and business phases of the construction industry.

The presentation and the examples illustrating financial-arithmetic problems are simple and direct. Thus the text can be helpful to beginning students in this field. The presentation is not accurate, however, in regard to the economic issues involved. For instance, while recognizing that the value of a physical asset may be affected by economic or technological changes, the author defines depreciation as the effect of the deterioration or the "wearing out" of the asset due to its use and the action of elements (p. 106). This concept was current in engineering circles many years ago. Outdated techniques appear also in the approach to the concept of annual cost: " ... our study of finance is based on the assumption that the economic and technological conditions existing at the instant of time under consideration remain permanent" (p. 139). A later reference to the "dynamic nature of our economy" is too casual to correct this error. A similar error appears in the discussion of capitalized cost (p. 151). Current practice, in which rapid obsolescence frequently dictates the choice

of an asset of short life expectancy, is overlooked. No reference is made to the present-day techniques of planning capital expenditures.

The presentation lacks precision in other respects. For instance, the statement in reference to the cost of installation is "these fixed expenses being irretrievable, immediately become one of the constituents of depreciation". In the same paragraph: "Aside from the question of obsolescence due to technological improvements or change in style (which we are excluding from consideration), there is an inevitable loss in the market value of an asset once it has been purchased and has acquired the appellation of 'secondhand'". (Pp. 157-8; emphasis supplied.)

In the chapter on legal and business phases of the construction industry and index numbers, the author attempts to condense too much in too little space. The review of the highlights of contract law, condensed in a dozen pages, can be useful to refresh the recollection of those familiar with the field. It is not adequate by itself, and it may be dangerous if used as a reference book by a novice who may assume that it gives him adequate legal information.

The same chapter describes in twenty pages the techniques of bidding in construction contracting and the use and application of construction cost index numbers. Further inclusion in this particular chapter of the standards of ethics of the engineering profession is somewhat anomalous. This subject is too important to be narrowed down, even by inference, to the engineer's activities in any specific field.

This text might provide a candidate for a license to practice professional engineering with adequate information for the engineering economy part of the examination, particularly in those states in which the engineering economy questionsare still based on the traditions of financial arithmetic and include a question on contract law and on canons of ethics. The author, however, claims that the text is designed for use as a college course in engineering economics and as a reference book by practicing engineers and others, as well as for preparation for examinations

for a professional engineer's license or for positions in governmental service (Preface, p. VIII). With this I must strongly disagree. I would not recommend this text for use in a college, nor as a reference book to a practicing engineer. Several more complete and more carefully written volumes are listed in the bibliography on pp. 257-8 of this text.

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THE 1959 SUMMER SYMPOSIUM

Symposium papers and related discussions on the subject of "Planning and Justifying Capital Expenditures" are still available. These papers were presented at the 1959 Summer Symposium of the Engineering Economy Division of the American Society for Engineering Education and the Engineering Economy Research Committee of the American Institute of Industrial Engineers. They are addressed to students and practitioners in the field of capital investment, and cover five major topics:

1. Capital Budgeting and Project Justification.
2. Post Auditing.
3. Estimation of Working Capital Requirements for Long-Range Planning.
4. Effects of Taxes on Investment Decisions.
5. Evaluating Uncertainty.

Copies of the papers may be obtained by filling out the form below and sending it to THE ENGINEERING ECONOMIST, Stevens Institute of Technology, Hoboken, N. J. The price is $4 for members of ASEE and AIIE, for educators, schools, and all libraries, and for those who attended the Symposium; and $10 for others.

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BOOK REVIEW

A Review of: THE CAPITAL BUDGETING DECISION
By Harold Bierman, Jr. and Seymour Smidt
The Macmillan Company, New York, 1960
246 pp. $6.00

By: W. B. Thulin, Comptroller
The Chesapeake and Potomac Telephone
Company of Virginia

The future success of a corporation may depend on the investment decisions made today. Yet many businessmen, in making these decisions, use intuition, rules of thumb, or methods based on faulty theoretical foundations. This book is designed to help business managers evaluate investment proposals. The authors suggest the present-value method for determining which investments to accept and which to reject.

Any present-value method requires some specified discount rate. It is suggested that the firm's "cost of money" is the appropriate discount rate. The main thesis of the book is developed in the theoretical situation where a firm can procure whatever money it needs at a going cost of money. The assumption is that each firm has a determinable cost of capital and that this should be used in computing the present value of an estimated cash flow.

There are several other important assumptions on which the authors predicate the suggested procedures. One is that the basic goal of the corporation is to maximize profits (quantitative dollars of profit), and that this goal is the same as maximizing the well-being of present stockholders. A second assumption is that the choice of investments should not be influenced by the method of accounting the firm uses, but only by the amount and timing of the cash flow the investment produces. A third assumption is that the optimum depreciation method for any investment is the one which minimizes the total income tax applicable to the investment's cash flow.

It is in this framework of theory that the authors present their well reasoned arguments for using the present-value technique. They contend that the yield method (also called the return on investment, discounted cash flow, investor's method, and other names) can give wrong answers. For example, assume that a company whose cost of capital is 10 per cent is confronted with the choice of investment A, requiring an outlay of $10,000 with cash proceeds of $12,000 next year, or investment B, requiring an outlay of $15,000 with cash proceeds of $17,000 next year. The yield of A is 20 per cent and that of B is 18 per cent. A quick answer would be that A is more desirable on the hypothesis that the higher the yield the better the investment. To see why this answer may be wrong, consider that a yield of 1000 per cent on an investment of a dime is a poor substitute for a yield of 15 per cent on $1,000, if only one of the investments can be undertaken.

They concede, however, that the yield method may help to dramatize the desirability of an investment by telling the practical businessman how much elbow room he has. It is helpful to know if the yield is 60 per cent or 10.1 per cent, when the cost of capital is 10 per cent. A net present value may result from having made cash outlays of $5,000 or $5 million. When the two methods lead to different decisions, the present-value method tends to give better decisions. It is simpler, safer, easier, and more direct.

Moving on to fields of application of the present-value method, several chapters are devoted to classifying investments by types, to timing of replacements, to considering alternatives, to income tax effects, and to allowing for the element of uncertainty. These chapters represent well crystallized views, succinctly and carefully presented. As an aid in selecting the particular depreciation method which would minimize income-tax effects of the project under study, tables are appended that give the present value of depreciation charges, at varying rates of discount for varying lengths of life, for the sum-of-the-years-digits method, and for twice-straight-line-declining-balance method. There are

also tables showing present value of $1 and present value of $1 received per period.

Two chapters are devoted to a discussion of cost of capital. A firm's cost of capital is developed by weighing the cost of each type of capital in accordance with the market value of the securities representing the source of the capital. The cost of equity capital can be measured by comparing expected future dividends to the present market value of the common stock. The expected future dividends are determined by applying an annual percentage rate of increase to the current dividend rate. The authors point out that no precise cost of capital is obtainable, nor is it necessary. Using an approximation of 5 per cent as against an actual cost of 8 per cent (determined by some as yet undiscovered procedure) would still generally give the same positive and negative present values, using either 5 per cent or 8 per cent. The only weakness would be the failure to attain the theoretical maximum of the economic well-being of the stockholders.

The authors recognize that capital rationing in one form or another exists in most corporations. They discuss the application of the present-value method to situations involving both external and internal capital rationing.

The concluding chapter is written in the form of a manual, complete with forms showing appropriation requests, estimated cash flows, tax savings from depreciation, and computation of present values. Appended, in addition to the computed tables, are a bibliography and a set of do-it-yourself problems illustrating the types of decisions discussed in the body of the book.

Professors Bierman and Smidt have produced a careful treatment, covering all types of investment decisions a firm is likely to encounter. While the discussion proceeds largely within a theoretical framework, the authors freely concede the necessity of recognizing, and providing for, deviations and modifications to fit the real-life world. The book is written in an easy-to-read, non-technical style. All financial executives and financial analysts will find something worthwhile in this little book, even though they may well argue that the theory doesn't fit their particular firms' situations.

BOOK REVIEW

Review of: THE APPRAISAL OF CAPITAL EXPENDITURE
By C. D. Edge
Published by the Society of Industrial and Cost Accountants of Canada, 31 Walnut St. S., Hamilton, Ontario, Canada
76 pp. Paperback. $3.00. Distributed without charge to registered and general members of the Society.

By: Arthur Lesser, Jr., Head
Department of Industrial Engineering
Stevens Institute of Technology

This report of 76 pages, including 25 pages of compound-interest tables, is directed to practicing Canadian industrial accountants. It is divided into four sections:

(1) A review of the progress of accounting and an analysis of the skills required to appraise capital expenditures;

(2) a brief explanation of the discounted cash-flow method of appraising capital expenditures, and its rationale;

(3) formal procedures for preparing, reviewing and approving capital expenditures; and

(4) examples of computations using the annual-cost method and discounted-cash-flow method.

For readers unfamiliar with the discounted-cash-flow method, the report is very useful as a primer, which is what it is designed to be. In discussing misconceptions of the discount method, the author cites, as one misconception, the requirement that the cash recovery through depreciation must be reinvested to enable a stipulated return to be earned. As proof, he reproduces a table showing that the rate of return on the unrecovered investment of $10,000, over a 5-year period, remains constant, without reinvestment of the cash recovery each year.

As the reviewer sees it, it is really not a question of a misconception, but rather of how the problem is conceived. If the

investor is interested in the $10,000 as an entity over the 5-year period, then he must consider reinvestment of the periodic cash recovery. On the other hand, if he is interested only in the earnings on the declining balance, after deducting the cash throw-offs, then the problem of cash reinvestment can be neglected. Theoretically, we are interested in the fate of the $10,000, as an entity, over the 5-year period. As a practical matter, we will settle for not considering the problem of reinvestment, because it would be necessary to evaluate a series of reinvestments, which would be awkward to handle and would be of doubtful utility.

The most interesting contribution of the report is the section on administrative procedures for initiating, processing and controlling capital expenditures, since these problems, with few exceptions, are generally overlooked in the literature. Although he considers the mechanics of administrative procedures, he goes much beyond them. He says that "there is much to be said for not having a prescribed format [for capital-expenditure requests] since there is infinite variety in circumstances met in appropriation requests." In reference to projects involving expansion, which he says are the most difficult to evaluate, he suggests that consideration be given to the "strategic" rate of return on investment, as well as the tactical rate of return. He conceives the tactical rate to be the rate of return on the project itself, as differentiated from the strategic rate of return on the project, which considers the long-term over-all return on all existing facilities, as well as the project under consideration. Too little attention is given in the literature to questions of investment strategy.

The author's conclusions on the administrative section of his report indicate, briefly, his well-thought-out views on this subject. They follow:

"Formal procedures for initiating, preparing, reviewing and approving appropriation requests appear to be widely adopted. They possess several advantages.

"Standard terminology, estimating techniques and methods of appraisal enhance the comparability of appropriations arising in

different parts of a company.

"The requirement that certain facts are needed in support of each type of appropriation, that the reasons for the appropriation are to be set forth in a report, and that the report is to be reviewed by the principal managers of a company, all tend to promote increased objectivity.

"Because these procedures encourage decisions throughout the company to be made in the same way, authorities for approving expenditures can be delegated with greater confidence.

"Finally, standardisation of preparation and appraisal enables senior management to concentrate more fully on the strategic and intangible aspects of major expenditures, since it is these which often have the greatest impact on the long term future of the Company."

The reviewer would like to recommend, as being well worthwhile, the reading and study of this report for the contents of this section.

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BOOK REVIEW

A Review of: RAILROAD EQUIPMENT FINANCING
By Donald MacQueen Street
Columbia University Press, 1959
177 pp. $6.00

By: Louis Siegelman, Economist
Business and Economic Research Department
The First National Bank of Chicago

This little monograph is the first definitive treatment of the financial aspects of equipment obligations since Kenneth Duncan's effort in 1924.

Dr. Street presents his case in logical fashion. The book begins with a statement of the increasingly important role played by equipment obligations in the capital expenditures of Class I railroads over the last 35 years, and of their growing proportion of non-current railroad debt (1.1 per cent in 1890, 8.0 per cent in 1929, 26.0 per cent in 1955). Rather sizable space, relative to the book's total length, is then devoted to the history of these financing media and their legal status. The strength and ultimate investor-safety of equipment certificates is neatly reaffirmed in a short chapter on "Experience in Receivership and Reorganization", at which point the reader has been carried midway through the book.

The remaining half of the book, really the heart of the subject, is a treatment of the major financing plans under which the railroads obtain the services of their rolling stock. The thoroughness of Dr. Street's approach tends therefore to weaken the effectiveness of the total impression, by what seems to me to be a misallocation of space within this fairly narrow field of finance. The Philadelphia (Lease) Plan, the Conditional Sale Plan, and the true leasing arrangement of more recent vintage are described in detail in individually assigned chapters, then followed by a very good chapter on the marketing of equipment obligations. The book concludes with a short statement indicating the author's optimistic

view of the outlook for these financing instruments and a lukewarm vote for the Symes proposal, which recommends the establishment of a government agency to acquire rolling stock and lease them to the railroads -- as a supplement to the traditional methods.

Dr. Street's book is a thorough treatment of a rather limited, though important, aspect of corporate finance. Perhaps the nature of the subject is such that it does not lend itself to a more readable style, for great amounts of technical and legal detail cannot be avoided. On the other hand, the author does succeed on several occasions in recapturing his reader's interest, so that I cannot help feeling that greater and more consistent efforts along these lines might have proved worthwhile.

If this were the book's only failing, it could still serve admirably well as a handy reference on the subject of equipment financing. But in returning to its pages I find that one cannot quickly pull out the answers to questions that might be posed. The index is quite complete, and so is the text treatment. It is therefore difficult to put a finger on the uneasiness I experience in using the book. Perhaps a summary at the end of each chapter, separating the significant points from the frequently confusing detail, would have been a useful device to employ.

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THE 1962 SUMMER SYMPOSIUM

This Symposium is now being planned to precede the 1962 Annual Meeting of the American Society for Engineering Education, scheduled for June 18th-22nd at the United States Air Force Academy.

THE ENGINEERING ECONOMIST will be happy to pass on, to members of the Planning Committee, any communications from our readers containing suggestions for the agenda. Announcements and news of the Symposium will appear in later issues.

THE ENGINEERING ECONOMIST
Stevens Institute of Technology
Hoboken, New Jersey

1962
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